

phase and synchronism relationship of mirror 103 and rotor 101 has been established, even in the instances when the strobe light is off the illuminating marker 108, the laser beam from laser source 107 continues to be locked in with the surface projection 112 of the point of imbalance 111.

Refer to FIG. 11. The rotor 101 is shown at top dead center (T.D.C.) rotational position of the point of imbalance projection 112. The rotation of the mirror 103 is still locked in phase and synchronous relationship with the rotation of the rotor 101. The point of impingement of the laser beam from source 107 which is reflected from the face of the mirror 103, continues to impinge upon the point of imbalance of the rotor 101.

Refer to FIG. 12. The point of imbalance 111 and its projection 112 upon the face of the rotor 101 and the locus of striking upon the face of the rotor 101 by the laser beam from source 107 which is reflected from the mirror 103 are both now at bottom dead center (B.D.C.). Even though the strobe light 105 is off at this instant, the beam is hitting the projection 112 of the point of imbalance 111.

Refer to FIG. 13. In this embodiment, identical elements (and so numbered) are provided except that the support is modified by providing an aperture 117 through the mirror support 116, by providing a half transparent mirror 118 and by positioning the strobe light 119 such that it impinges upon the face of the rotor 101. The half transparent mirror 118 is disposed angularly to the axis of the beam emitted from source 107 toward the center of the mirror 103 and is oriented such that the laser beam from source 107 passes through the half transparent mirror 118, strikes the mirror 103 and is reflected onto the face of the rotor 101 at the projection 112 of the point of imbalance 111. The light rays reflected from the surface projection 112 of the point of imbalance illuminated by stroboscopic light 119 are reflected from mirror 103 to the half transparent mirror 118 whence they are reflected back to the viewer shown at 110. This enables the viewer at 110 to view the point where the laser has impinged or will be impinging through the aperture 117. A slit could be provided in place of the aperture 117 if desired. Either of these alternate embodiments would provide visual aid helpful in monitoring the balancing operation.

It will be understood, of course, that in the embodiments shown in FIG. 13, also means to provide synchronism and locked in phase relationship between the rotation of the rotor 101 and the rotation of the wobbling mirror 103 would be provided for example, by synchronizing and phase shifting means (not shown) disposed between the motors 102 and 104.

While salient features have been illustrated and described with respect to particular embodiments, it should be apparent that modifications may be made readily within the spirit and scope of the invention. It is therefore not desired to limit the invention to the exact details shown and described. For example, in the FIG. 3 embodiment, optionally, a section of the cone 63 can be flattened to provide the function of flat mirror 62 or alternatively a flat plane surface not necessarily of the trapezoidal shape of mirror 62 could be attached along a longitudinal axis tangential to the conical surface 63. Obviously, alternative ways of phase shifting and alternative types of motors, mounting means, and optical and electrical parts might be employed. As pointed out hereinabove, variations in lateral, rotational and vertical positioning of the rotor, laser beam emitter, and mirrors or optical units may be interchanged so as to arrive at the correct spacial and orientation parameters required for balancing. Many optional mechanical, electrical, and other variations of the means for adjustment and of these elements are possible without departing from the spirit and scope of the invention. For example, instead of utilizing a wobbling mirror or a flattened conical mirror, various types of wobbling lens, wobbling thick glass plates and electro-optical beam deflectors may be provided additionally to those shown and can satisfy the criteria of capability of synchronous and in phase movement with the rotation of the rotor to assure zero relative motion between the beam

deflecting means and the rotor so that the beam may constantly impinge upon the rotor.

There thereby has been shown a means for balancing a rotating element by moving a material removing means in phase and synchronism with the rotating component, permitting the separate control of energy from the removing means and wherein is obviated the need for critical control of the firing for removal time of the means utilized. The necessity for irregular gouges resulting from dynamic balancing is also eliminated or minimized by the inventive optical scanning device. Capability of the invention has been shown of rotationally displacing a focused laser beam in synchronism with the rotation of the rotary element to be balanced in such manner that the laser beam will always impinge on the same selected spot on the periphery or sides of the rotor while the imbalance remains and wherein the angular location of imbalance on a rotating element may be sensed, the phase relationship between a scanner head and the rotor may be coincided, the firing of the laser beam may then be made continuous and these steps can be carried out without stopping the rotating element, without time consuming extra manipulations, so as to enable removal of material by a laser pulse, wherein the duration of the pulse will have no effect on the size or shape of the volatized area and in a manner permitting accurate removal of imbalance.

What is claimed is:

1. Apparatus to dynamically balance a rotary body comprising:

- a. means to rotate the rotary body,
- b. a source of a beam of energy capable of rendering material of said body removable,
- c. means to deflect said beam of energy in a path terminated by impingement upon a selected portion of the surface of the rotary body,
- d. means to effect motion of the path of said deflected beam, and
- e. means to control said motion of the path and said means to rotate said rotary body to effect substantially synchronous and in phase movement of said beam path impingement and said selected portion.

2. The apparatus of claim 1 wherein:

- a. said means to rotate the body further comprises means to rotate the body at normal operating speed,
- b. said source and said means to deflect said beam further comprises means to supply concentrated laser beam energy to said rotary body, and
- c. said means to effect motion of the path further comprises means to deflect said beam into a rotating path wherein the beam impinges upon the area comprising said selected portion of the rotary body surface.

3. The apparatus of claim 1 wherein said selected portion of the surface is a portion of equivalent imbalance, said control means further comprising:

- a. means to sense imbalance of said rotary body, and
- b. means responsive to said sensing means to retain the apparatus in enabled condition such that the beam continues to impinge upon said selected surface until sufficient energy has been delivered to remove the equivalent imbalance of the rotary body.

4. The apparatus of claim 1:

- a. said means to deflect further comprising an optical scanner having a beam deflecting face angularly disposed with respect to the plane normal to said rotary body axis,
- b. means to support and rotate said optical scanner, and
- c. means to adjust the relationship between said scanner and said rotary body such that the beam deflected by said scanner is deflected to impinge radially outwardly from the axis of said rotary body a distance substantially equal to the distance that the selected portion is disposed radially outwardly from the axis of said rotary body.

5. The apparatus of claim 4:

- a. said supporting and rotating means further comprising means to support and rotate said optical scanner about an